Percent Composition of Water in a Hydrate

Introduction

All samples of a pure substance have a definite chemical makeup regardless of sample size or source. This is known as the law of definite composition. Thus any sample of a compound will contain the same percentage of each element. In the experiment described here, a sample of copper (II) sulfate that had absorbed some water ($CuSO_4 \bullet xH_2O$) creating a hydrate was analyzed to determine the percentage of water present. According to the law of definite composition all samples used would yield the same percentage of water.

In compounds, atoms of elements combine in small whole number ratios. The formula showing the simplest ratio of elements in compounds is called empirical formula. From the percentage of each element in a compound, empirical formulas can be determined by finding the molar ratio between the elements present. After the percentage of water present in the $CuSO_4 \bullet xH_2O$ was calculated, the molar ratio of $CuSO_4$ to H_2O water was deduced and the empirical formula found.

Methods

First the mass of an empty evaporating dish was taken and recorded. Following this, about 2 g of $CuSO_4 \bullet xH_2O$ were added to the dish and the mass was again taken and recorded. The dish was placed on wire gauze resting on an iron ring and heated with a Bunsen burner (shown in figure 1).

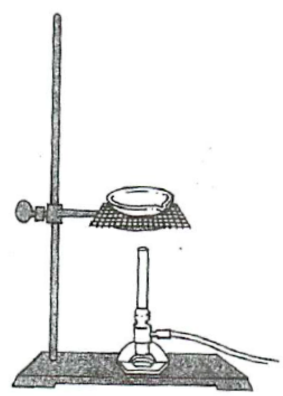

Figure 1: The evaporating dish was supported with an iron ring and wire gauze and heated over a Bunsen Burner. (Image scanned from the lab handout)

As the blue hydrate was heated it began to turn white. It was stirred with a glass stirring rod and it began to clump. These clumps were broken up with the rod. Once the sample turned completely white/dull grey, the dish was removed from the heat and placed on a cooling tile using crucible tongs. After the dish was cool to the touch, the final mass was recorded and the contents of the dish were disposed of by the instructor.

Results

Table 1 below shows the raw data collected during the experiment.

Table 1: Raw Data

Mass of the Empty Evaporating Dish (g)	46.59
Mass of the Evaporating Dish with $CuSO_4 \bullet xH_2O$ (g)	48.59
Mass of the Evaporating Dish after Heating (g)	48.00

Table 2 below shows the calculated data from the experiment. All calculations were performed in the lab notebook.

Table 2: Calculated Data

Mass of the Hydrate Used (g)	2.00
Mass of the Water Lost (g)	0.59
Percent Water in the Hydrate	29.5%
Percent Error	18.1%
Empirical Formula of the Hydrate	$CuSO_4 \bullet 4H_2O$

Discussion

To determine the percentage of water in $CuSO_4 \bullet xH_2O$, a sample of the hydrate was heated and the following reaction took place:

$$CuSO_4 \bullet xH_2O(s) \rightarrow CuSO_4(s) + xH_2O \uparrow$$

Based on the change in mass of the sample as water evaporated from the crystals, the percent water could be determined from the following calculations. First, the mass of the hydrate used was determined by subtracting the mass of the empty evaporating dish from the mass of the dish with the hydrate. Then the mass of the water evaporated was found by subtracting the dish after it was heated from the dish with hydrate before it was heated. This mass of water lost was then divided by the original mass of the hydrate and multiplied by 100% to find that there was 29.5% water present in the salt.

The actual percent of water in the hydrate is 36.0%, so the experimental value is 18.1% lower than it should be. This is most likely due to not all the water being removed from the hydrate during heating. If not all the water was lost, the mass of the anhydrous salt at the end of the experiment would be higher than expected. So less water would be appear to be present in the hydrate leading to a lower percent water. There could also be some water from the air absorbing in the anhydrous salt as it cooled. However, the mass was taken immediately upon cooling so any water absorbed would be negligible. The experiment could be improved by heating the sample to a constant mass to ensure that all the water was removed.

Finally, from the percentage of water present in the hydrate the empirical formula was determined. This calculation was done by converting the masses of $CuSO_4$ and H_2O each to moles using their molar masses. Then the number of moles of each were divided by the smallest number of moles to obtain a 1:5 whole number ratio of $CuSO_4$ to H_2O. Thus the empirical formula of the hydrate was $CuSO_4 \bullet 5H_2O$. Note that the actual percent of water was used for this calculation. Using the experimentally obtained percent of water would result in the empirical formula being $CuSO_4 \bullet 4H_2O$.

All samples measured by the class were between 28% -35% water. This supports the law of definite composition, which states that all samples of a pure substance have the same chemical makeup regardless of source or sample size. Since the class all used samples of the same hydrate, it stands to reason that each group would obtain the same percent of water.

This lab showed that simply heating a sample of a compound containing water could successfully reinforce many core concepts in chemistry. The percent composition and empirical formula of the compound were easily determined. Also law of definite composition, a major governing law in science, was also illustrated when all samples were analyzed collectively.